GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: June 27, 1977

Project Title: Evaluation of Thermal Resistance of Selected Carpet Samples

Project No: E-27-656

Project Director: Dr. L. Howard Olson

Sponsor: Hoechst Fibers Industries; Spartanburg, SC 29304

Agreement Period: From 6/15/77 Until 8/31/77

Type Agreement: Std. Ind. Res. Agree. dated 6/8/77

Amount: $1,300

Reports Required: Final Report

Sponsor Contact Person (s):

Technical Matters

Mr. Tony Shaw
Hoechst Fibers Industries
P.O. Box 5887
Spartanburg, SC 29304

Contractual Matters
(thru OCA)

Defense Priority Rating: n/a

Assigned to: Textile Engineering (School/Laboratory)

COPIES TO:

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GEORGIA INSTITUTE OF TECHNOLOGY
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SPONSORED PROJECT TERMINATION

Date: 9/20/78

Project Title: Evaluation of Thermal Resistance of Selected Carpet Samples

Project No: E-27-656

Project Director: Dr. L. Howard Olson

Sponsor: Hoechst Fibers Industries

Effective Termination Date: 7/31/78

Clearance of Accounting Charges: 7/31/78

Grant/Contract Closeout Actions Remaining:

X Final Invoice ~~and Closing Documents~~
_ Final Fiscal Report
_ Final Report of Inventions
_ Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other ____________

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CA-4 (3/76)

E-27-656

Evaluation of Thermal Resistance of
Selected Polyester Pile Carpet Samples

I.) Introduction

The objective of this work was to evaluate the thermal resistance of ten carpet specimens containing polyester pile fiber. Thermal resistance or R-value is a standard measurement used by the building construction industry, for example, to evaluate the insulating quality of a building material. The sum of R-values of individual components of a structural composite such as an exterior wall gives the R-value of the wall for heating or cooling load estimation.

At this time of energy consciousness, with increased efforts to conserve energy as energy costs increase, all components of residential and commercial structures are subject to investigation with respect to energy efficiency. A report by Georgia Tech[1] on work recently completed showed that floor heat losses could be significant and that carpeting could reduce floor heat loss.

II. Technical Approach

The selection of ten polyester pile carpet samples was carried out by Mr. Tony Shaw of Hoechst Fiber Industries, and those samples delivered to Ga. Tech. The samples were identified solely by sample numbers 2-0031-1A through 2-0331-1I and 2-0331-1K. On the remainder of this report the samples are referred to as A through I and K.

In order to establish the physical characteristics of the carpet samples, the total height, pile height and total weight were determined by normal test procedures. These measurements were repeated independently by Dynatech R & D Company and by Hoechst with close agreement of the results (± 5%).

[1] Birchfield, J.L., Combes, R.S., and Olson, L.H., "Advantages of Rugs and Carpeting in Energy Conservation", Nov. 1976.

Thermal transmittance testing was carried out by Dynatech R & D Company, Inc., an independent testing firm, preeminent in the field of thermal conductivity testing and the largest in the world in this field. The test method used as ASTM C-518 for determining thermal transmittance. The test conditions include a half-inch air gap above the carpet for which the Grashof number[2] indicated negligible convective heat flow. Thus, the measured resistance of the air gap could be subtracted from the overall thermal resistance of carpet plus air gap to yield the carpet thermal resistance. By this means, carpet pile deformation was avoided. The analysis of results involved finding linear regression coefficient, average and standard deviation for the measured samples.

III. Test Results

The results of tests on the polyester pile carpets to determine thermal resistance and the other physical characteristics are presented in Table 1. The average R-value of these carpets per inch of total thickness is R = 2.19 with 6% coefficient of variation. This number may be compared with R = 3.2 per inch for fiberglass batting, which is the best of the popular building insulation materials.

The slope obtained by linear regression techniques is similar to the average obtained above, but uses different weighting. The data was forced toward a zero intercept point with the results that an R value of 2.09 per inch thickness was obtained. The goodness of the fit as determined by the regression coefficient on a scale of 0.0 to 1.0, 1.0 being a perfect fit, was 0.994.

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[2] F. Krieth, Principles of Heat Transfer, Intext Educational Publishers, New York, (1963).

Table 1

Results of Polyester Pile Carpet Measurements

Sample No.	Total* Height	Pile* Height	Total Weight	Pile** Weight	R*** Value
A	0.84	0.63	83.7	47.7	1.83
B	1.29	1.16	122.3	67.4	2.56
C	0.82	0.76	93.5	49.1	1.90
D	0.77	0.67	80.4	35.0	1.71
E	0.95	0.78	103.7	63.0	1.90
F	0.64	0.50	76.0	36.6	1.56
G	0.70	0.67	84.8	44.9	1.61
H	0.88	0.72	88.7	55.2	1.90
I	0.89	0.80	88.6	51.4	1.96
K	1.04	0.86	108.6	~~40.1~~ 71.5	2.19

* Height measurements are in inches.

** Weight measurements are in oz./yd^2.

*** R-value has units of (hr.-$ft.^2$ - °F/BTU).

IV. Conclusions

The evaluation indicates that polyester pile carpeting has an insulation effectiveness of roughly two thirds that of fiberglass battings. In a "cold floor" application, the carpets will reduce energy loss. The degree of insulating value increases with total carpet thickness which in turn is directly related to the height and weight of the polyester pile of the samples evaluated.

The consistency or low variation of the numerical results indicates strongly that R-value can be reliably identified and assigned to individual styles of constructions of polyester pile carpeting.

E-27-656

Final Report to Hoechst Fibers Industries
on Thermal Resistance of 52 Carpet Samples

Thermal resistance measurements on fifty-two carpet samples designated as 2-0412-A through Z and 2-0415-A through Z were undertaken. Tests were performed by Dynatech R & D Company, an independent thermal measurements laboratory, on the samples to determine thermal transmittance, total thickness and composite density. The resultant data was reduced to determine thermal resistance or R-value at Georgia Tech and compared with areal density and total thickness measurements found at Georgia Tech.

The results show agreement with previous work on carpet thermal resistance in that carpet total height has a greater correlation to R-value than does carpet density. This occurs because the primary insulation mechanism is the air trapped between fibers, just as it is in fiberglass home insulation products. Two carpets of equal total pile heights will generally have comparable R-values despite a difference in pile density. The insulating property of the air trapped between fibers is relatively constant until the interfiber distance in the plane of the carpet exceeds approximately 1/8 inch. Typically, all carpets are constructed such that after yarn bloom, the inter-fiber distances are much smaller than 1/8 inch. Thus, normal carpet density variations in terms of tufts per square inch normally will have little effect on R-value. The total thickness of the trapped air layer has a significant effect.

The data on R-value, areal density, and total thickness are reported in

Table 1. The measurements of total thickness and areal density were conducted at both Ga. Tech and Dynatech. The number in Table 1 are those measured by Dynatech. The Ga. Tech measurements agreed on average to within 3% of the Dynatech measurements. R-values as reported in Table 1, are the measured value rounded down to one decimal place and have 0.1 subtracted from the rounded value. This was done to compensate for those samples which possible represented constructions near the upper limits of total height and density so that use of these R-values would apply over the normal range of carpet construction variations.

Table 1. Thermal and Other Measurements on Carpet Samples

Part A.) Samples Designated as 2-0415-A through Z

Sample No.	Areal Density ($oz./yd^2$)	Total Thickness (inches)	R-value ($HR\text{-}Ft^2\text{-}{}^oF/BTU$)
2-0412-A	124	1.26	2.3
B	91	0.82	1.7
C	88	0.83	1.7
D	71	0.68	1.5
E	90	1.06	2.0
F	87	0.87	1.6
G	70	0.78	1.5
H	97	0.90	1.9
I	78	0.64	1.3
J	72	0.79	1.3
K	82	0.77	1.4
L	89	0.80	1.6
M	99	1.02	2.0
N	79	0.62	1.1
O	90	0.80	1.7
P	73	0.72	1.4
Q	80	0.78	1.6
R	97	0.88	1.6
S	63	0.63	1.3
T	99	0.80	1.6
U	112	0.94	2.0
V	86	0.87	1.7

(Part A Continued)

W	93	0.62	1.3
X	87	0.76	1.5
Y	94	0.80	1.8
2-0412-Z	114	1.00	2.0

Table 1. Thermal and Other Measurements
on Carpet Samples

Part B) Samples Designated as 2-0415-A through Z

Sample No.	Areal Density ($oz./yd^2$)	Total Thickness (inches)	R-value ($HR-Ft^2-{}^oF/BTU$)
2-0415-A	85	0.84	1.7
B	85	0.94	1.9
C	77	0.72	1.4
D	78	0.80	1.6
E	86	0.98	2.0
F	90	0.90	1.7
G	102	1.05	2.0
H	81	0.82	1.6
I	86	0.82	1.7
J	77	0.82	1.7
K	83	0.65	1.4
L	75	0.75	1.6
M	82	0.72	1.4
N	97	0.99	2.0
O	85	0.80	1.6
P	88	0.93	1.9
Q	83	0.82	1.7
R	106	0.95	1.7
S	81	0.89	1.7
T	73	0.68	1.2
U	101	1.10	2.0

(Part B Continued)

V	104	1.08	2.2
W	107	0.98	1.9
X	77	0.56	1.0
Y	82	0.78	1.5
2-0415-Z	69	0.80	1.4

THE THERMAL TRANSMITTANCE OF
FIFTY-TWO CARPET MATERIALS

Prepared for:

Georgia Institute of Technology
School of Textile Engineering
Atlanta, Georgia 30332

Dynatech Report No. GIT-6
Work carried out under letter (L. Howard Olsen) on 23 March 1978

Submitted by: ______________________
A.O. Desjarlais
Project Manager
Thermatest Department

Reviewed by ______________________
Stewart C. Spinney, Manager
Measurements Laboratory
Thermatest Department

8 June 1978

DYNATECH

THE THERMAL TRANSMITTANCE OF FIFTY-TWO CARPET MATERIALS

Fifty-two carpet materials were submitted for analysis of the thermal transmittance.

Experimental Procedure

The samples were tested in accordance with ASTM C518-76, "Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter." The sample was placed between 300 mm square aluminum plates with blackened surfaces leaving an air gap of 12.7 mm between the top of carpet and the upper plate or hot plate. The upper plate contained a heater while the lower plate consisted of cooling chamber, a subsidiary heater and a multi-junction thermopile calibrated heat meter. At equilibrium conditions, the temperature of both hot and cold faces was evaluated from thermocouples embedded in the plates and the heat flux through the specimen was derived from the output of the heat meter.

The thermal transmittance was calculated from

$$C = (q/A)\left(\frac{1}{\Delta T}\right)$$

where C = thermal transmittance

q/A = heat flux

ΔT = temperature difference between hot plate 12.7 mm above top of sample and cold plate at the bottom of the sample.

The results for the samples tested are shown in the following tables.

Reference: GIT-6

June, 1978

Table 1

THE THERMAL TRANSMITTANCE OF TWENTY-SIX CARPET MATERIALS

DESIGNATED AS 2-0412

Specimen	Composite Density		Thickness(1)		Thermal Transmittance @ 21C(70F)	
	$kg\ m^{-3}$	$lbs\ ft^{-3}$	mm	inches	$Wm^{-2}K^{-1}$	$BTU\ hr^{-1}ft^{-2}F^{-1}$
A	130	8.2	32.1	1.26	1.8	0.32
B	145	9.2	20.8	0.82	2.25	0.40
C	140	8.8	21.0	0.83	2.25	0.40
D	140	8.7	17.2	0.68	2.5	0.44
E	115	7.1	27.0	1.06	2.05	0.36
F	135	8.3	22.0	0.87	2.4	0.42
G	120	7.5	19.7	0.78	2.45	0.43
H	145	9.0	22.8	0.90	2.1	0.37
I	160	10.1	16.2	0.64	2.65	0.47
J	120	7.6	20.0	0.79	2.65	0.47
K	145	8.9	19.5	0.77	2.6	0.46
L	150	9.3	20.2	0.80	2.35	0.41
M	140	8.8	26.0	1.02	2.0	0.35
N	170	10.6	15.7	0.62	2.9	0.51
O	150	9.4	20.2	0.80	2.25	0.40
P	135	8.5	18.4	0.72	2.55	0.45
Q	140	8.6	19.8	0.78	2.4	0.42
R	145	9.2	22.4	0.88	2.35	0.41
S	135	8.3	15.9	0.63	2.7	0.48
T	165	10.3	20.2	0.80	2.35	0.41
U	160	10.0	23.8	0.94	2.05	0.36
V	130	8.2	22.2	0.87	2.25	0.40
W	200	12.5	15.8	0.62	2.65	0.47
X	150	9.5	19.4	0.76	2.45	0.43
Y	155	9.8	20.4	0.80	2.15	0.38
Z	150	9.5	25.3	1.00	2.0	0.35

NOTE (1) The test was performed with an additional 12.7 mm (0.50 inch) air gap

DYNATECH

Table 2

THE THERMAL TRANSMITTANCE OF TWENTY-SIX CARPET MATERIALS

DESIGNATED AS 2-0415

Specimen	Composite Density		Thickness (1)		Thermal Transmittance @ 21C (70F)	
	$kg\ m^{-3}$	$lbs\ ft^{-3}$	mm	Inches	$W\ m^{-2}K^{-1}$	$BTU\ h^{-1}ft^{-2}F^{-1}$
A	135	8.4	21.4	0.84	2.25	0.40
B	120	7.6	23.8	0.94	2.1	0.37
C	145	8.9	18.3	0.72	2.55	0.45
D	130	8.1	20.2	0.80	2.4	0.42
E	115	7.3	25.0	0.98	2.0	0.35
F	135	8.3	22.9	0.90	2.25	0.40
G	130	8.1	26.6	1.05	2.05	0.36
H	130	8.2	20.8	0.82	2.4	0.42
I	140	8.7	20.8	0.82	2.25	0.40
J	125	7.8	20.8	0.82	2.25	0.40
K	170	10.7	16.6	0.65	2.6	0.46
L	135	8.3	19.0	0.75	2.4	0.42
M	150	9.5	18.2	0.72	2.55	0.45
N	130	8.2	25.2	0.99	2.05	0.36
O	145	8.9	20.4	0.80	2.35	0.41
P	125	7.9	23.6	0.93	2.1	0.37
Q	135	8.4	20.8	0.82	2.25	0.40
R	150	9.3	24.2	0.95	2.2	0.39
S	120	7.6	22.6	0.89	2.25	0.40
T	145	9.0	17.2	0.68	2.85	0.50
U	125	7.7	28.0	1.10	2.05	0.36
V	130	8.0	27.5	1.08	1.85	0.33
W	145	9.1	24.8	0.98	2.1	0.37
X	185	11.4	14.1	0.56	3.2	0.56
Y	140	8.8	19.8	0.78	2.45	0.43
Z	115	7.2	20.4	0.80	2.55	0.45

Note (1) The test was performed with an additional 12. 7 mm (0.5 inch) air gap.

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